ARMY RESEARCH LABORATORY

A Low-Velocity 0.22-Caliber Gun System

by Donald Little

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14. ABSTRACT
An efficient method was needed to perform ballistic testing using the 0.22-cal. fragment-simulating projectiles (FSP) at low subsonic velocities in order to evaluate very thin lightweight composite and metallic materials at around 1 lb/ft^2 areal density. This technical note outlines the custom gun system developed to enable this ballistic testing.

15. SUBJECT TERMS
0.22 cal., fragment simulating projectile, gun system

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1. Introduction

Research to find lighter materials for use in armor and protection applications is an ongoing process at the U.S. Army Research Laboratory (ARL). The main method used to evaluate and compare materials for use in armor applications is the V50 ballistic limit velocity test (MIL-STD-662F).[1] The V50 ballistic limit velocity is calculated using an equal number of impacts resulting in complete penetration (target loses) and partial penetration (target wins), this is achieved by raising and lowering the propellant load to obtain a pre defined velocity spread. Figure 1 shows the steel 0.22-cal., 17-gr fragment-simulating projectile (FSP)[2] used for evaluating materials at around 1 lb/ft^2 areal density. The reduced weight and thickness of these materials results in very low V50 velocities of 400m/s or lower. Testing in this regime is inherently a struggle controlling velocity from shot to shot and usually results in an excessive number of tests to define the V50. Figure 2 is a velocity curve for the 0.22-cal. FSP generated using a standard-length 0.22-cal. barrel and standard 0.22-cal. projectile propellant. The curve shows as the propellant is reduced, velocities are more unpredictable. Note that at a constant propellant load of 5.6 gr, the 0.22-cal. FSP could vary 30 m/s above or below the average performance line. Standard propellants used for the 0.22-cal. family of projectiles are engineered for bullet weights that are three times the mass of the 0.22-cal. FSP. Using these propellants to launch the light weight FSP does not work very efficiently due in part to the slow burn rate characteristics of these propellants. Experiments were done to develop a gun system to allow for a more efficient method of testing at low velocities.

2. Approach

An experimental barrel was constructed by cutting a standard 0.22-cal. Mann barrel down to a length of 11.5 in. The barrel has three lands and grooves and a twist rate of one turn for every 12 in of length. The chamber end of the barrel has a standard 1903 Springfield receiver thread to accept a thread on small caliber percussion initiated breech for firing the weapon. The chamber of the barrel was machined as a straight cylinder with a 0.376-in diameter and 0.750 in deep. Figure 3 shows the barrel mounted in place in the test fixture. A custom case to fit this chamber was machined from 17-4 PH stainless steel, as shown in figure 4. The internal dimensions were 0.193 in wide × 0.630 in deep. The priming pocket was machined to accept a standard small rifle percussion primer. The custom cases were heat treated as follows to give the correct temper: heat to 900 °F and hold for 1 h, then air cool to ambient temperature. This procedure increases the tensile strength and produces a hardness of 40-42 Rockwell C (RC) scale. Figure 5 is a drawing of the custom case that was produced and used for this testing.

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[1]MIL-STD-662F. *V50 Ballistic Test for Armor* **1977**.

[2]MIL-STD-46593B. *Projectile, Calibers 0.22, 0.30, 0.50, and 20-mm Fragment-Simulating* **2006**.

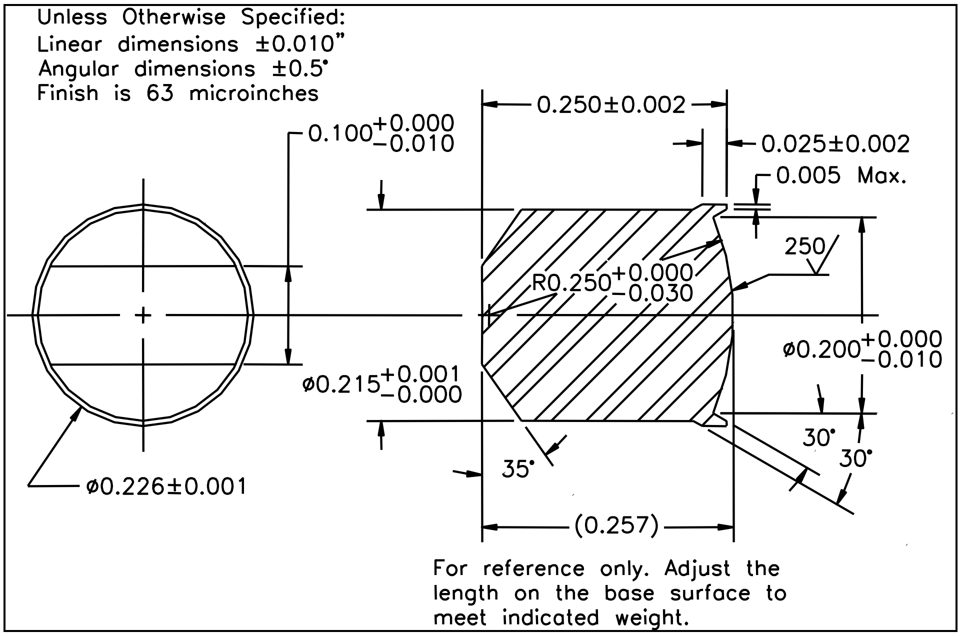

Figure 1. The 0.22-cal. FSP.

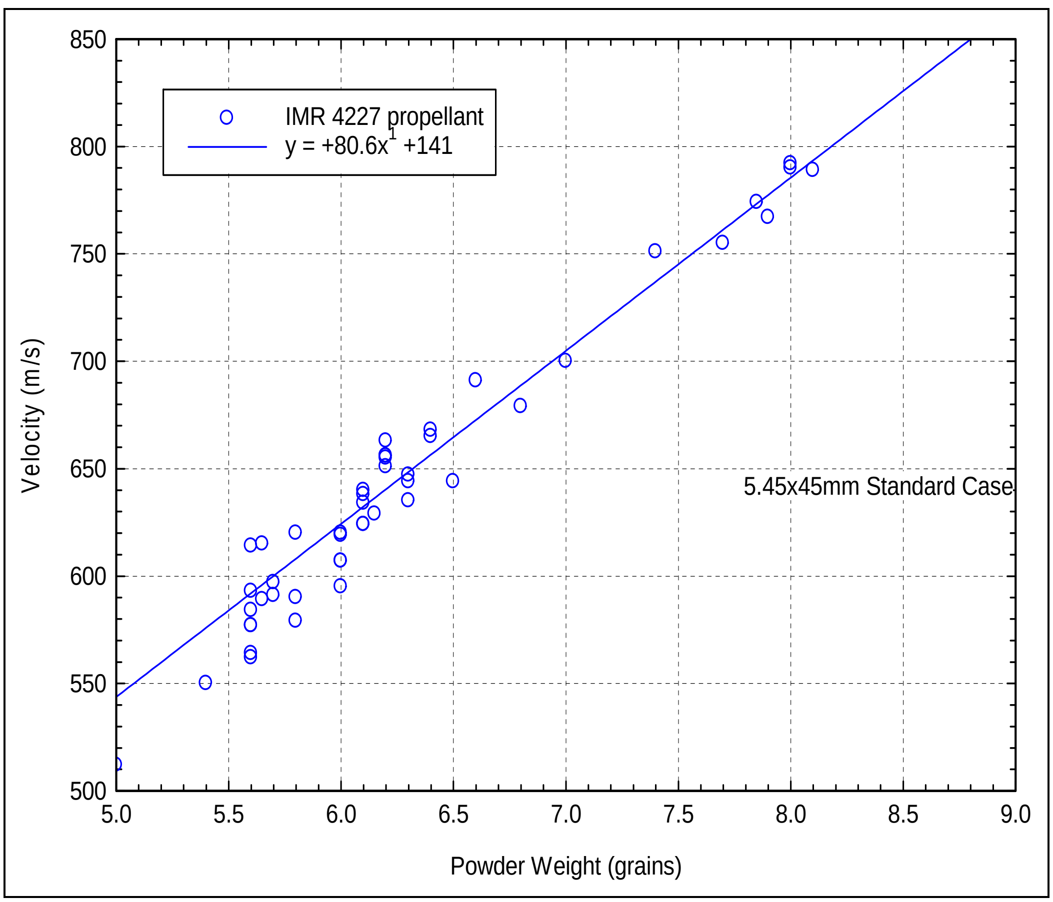

Figure 2. The 0.22-cal. FSP launch velocity as a function of propellant load for a standard barrel.

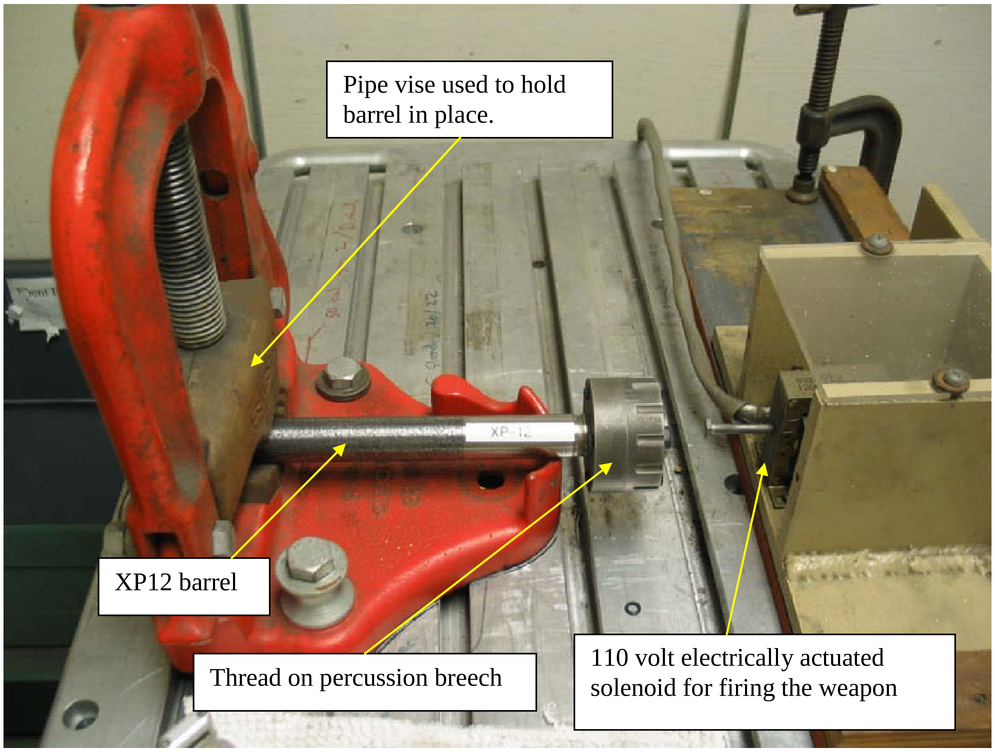

Figure 3. The XP-12 custom barrel in the firing fixture.

Figure 4. Photographs of the 0.22-cal. custom case.

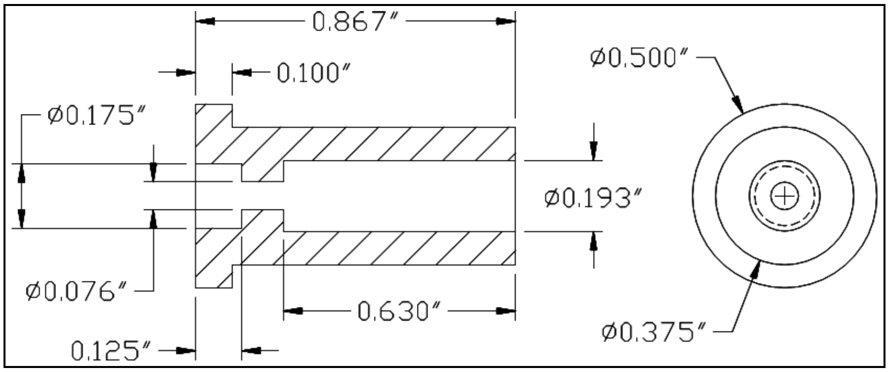

Figure 5. Dimensioned drawing of 0.22-cal. custom case.

3. Experiments and Procedures

Figure 6 shows the layout and parameters of the experimental facility with this gun system.

The FSPs used in these experiments were all first passed through a custom steel resizing die to achieve a more consistent and uniform flare diameter; this in turn reduced the variation of the fit of the fragments in the bore of the gun. The die was 17-4 PH stainless steel, 1 in long with a 1-in diameter and a precision 0.225-in-diameter hole machined through the center. It was heat treated to ~RC40 to reduce wear during use. Each FSP was then pressed or tapped through the 0.225-in hole. Another step taken to reduce variability in testing was sorting the FSPs by weight. After resizing and weighing a group of FSP's, ten were selected for testing that were within ±0.3 gr of one another.

Bullseye smokeless pistol powder, a very fast burning propellant manufactured by Alliant, was chosen for these experiments due to the light weight of the FSP. It was important to be meticulous when loading this cartridge to get consistent results. Loading often required the propellant to be weighed to 100th of a grain. To keep the propellant charge in place and evenly distributed inside the case, a small piece of tissue paper (~0.750-in diameter) was gently pushed down inside the case, using a small wooden dowel. The priming component used was a BR-4 Small Rifle Bench Rest percussion primer manufactured by Cascade Cartridges Inc.

It was equally important to precisely seat the FSP in the bore at the same depth for each test. A custom seating tool was built from a piece of all-thread rod. One of the custom cases developed for use in this system was then modified by machining a 0.235-in-diameter clearance hole through the center. This modified case was inserted in the barrel and used as an alignment tool to guide the FSP into the barrel and engage it into the rifling. Two locking nuts were added to set the stopping point of the seating rod against the back of the modified case. This seating tool was then adjusted to seat the fragment 0.062 in into the rifling of the gun. Figure 7 shows the different components made and used for this step.

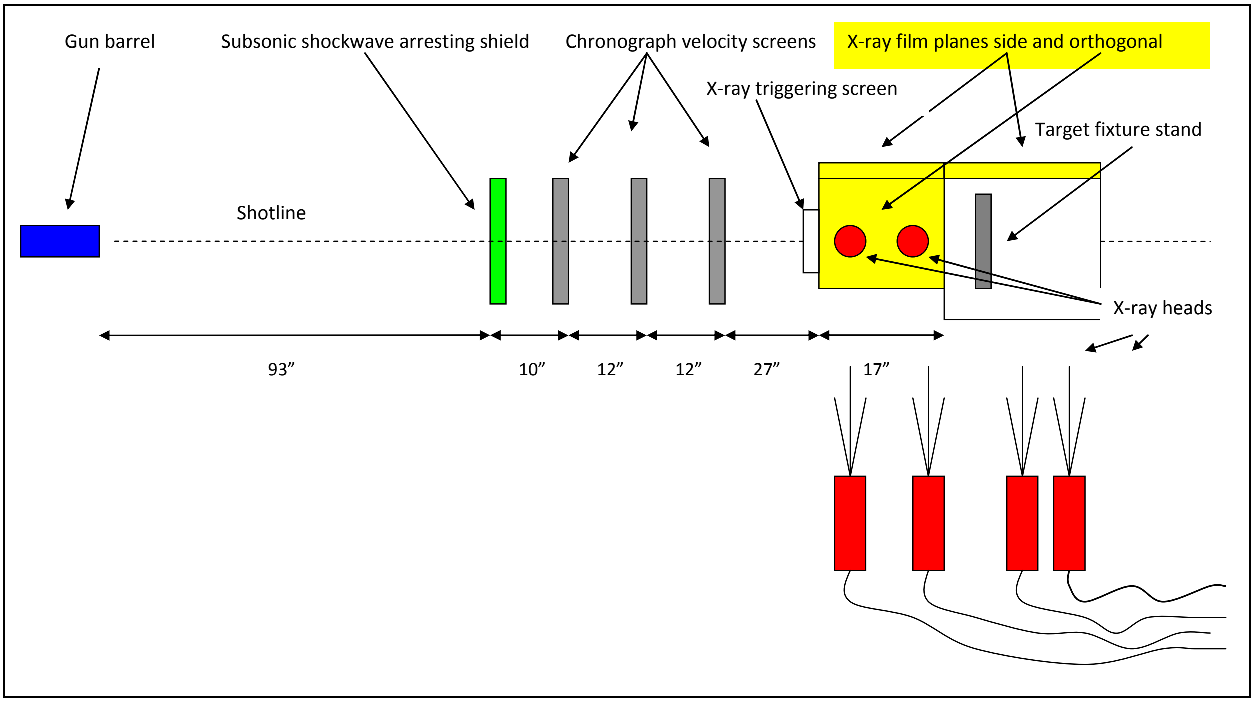

Figure 6. Overhead view of testing facility.

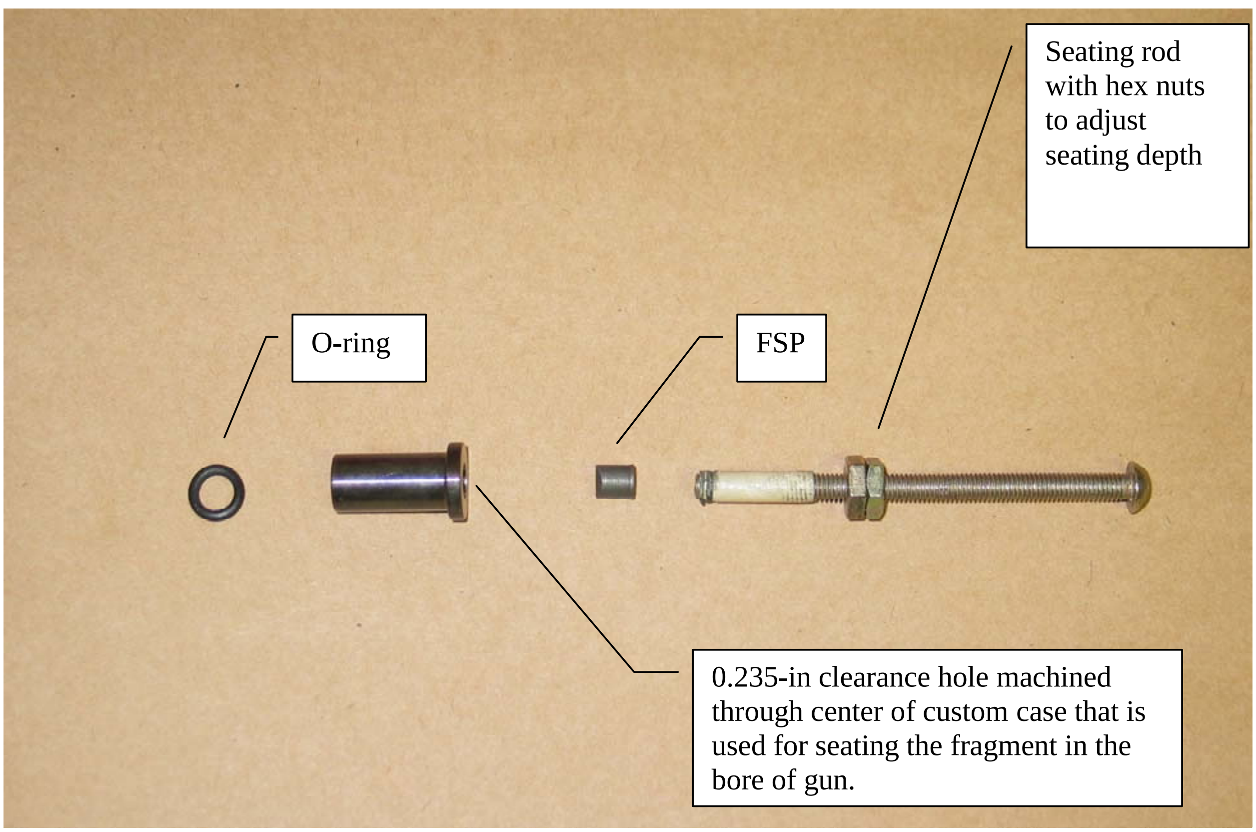

Figure 7. Tools used for seating the FSP into the gun system.

A standard AS568B #010 Black Nitrile rubber O-ring was inserted in the barrel ahead of the loaded case to help form a seal between the face of the case and the barrel to aid in preventing gases from escaping in this region and improve velocity consistency. After the fragment was seated and the O-ring was in place, the loaded case was inserted in the gun and the breech was then threaded on until it touched the back of the case; at this point it was given ~1/8 of a turn to add a slight compression on the O-ring. Tests done with and without the O-ring in place showed more consistent velocities were achieved when using the O-ring. When testing at lower velocities (300–400 m/s), the O-ring lasted ten or more shots before needing to be replaced. As the propellant load was increased, the O-ring needed to be replaced more frequently due to the increased pressure. Figure 8 is a cross section illustration that shows how the chamber end of the barrel was made and how the different components all fit together.

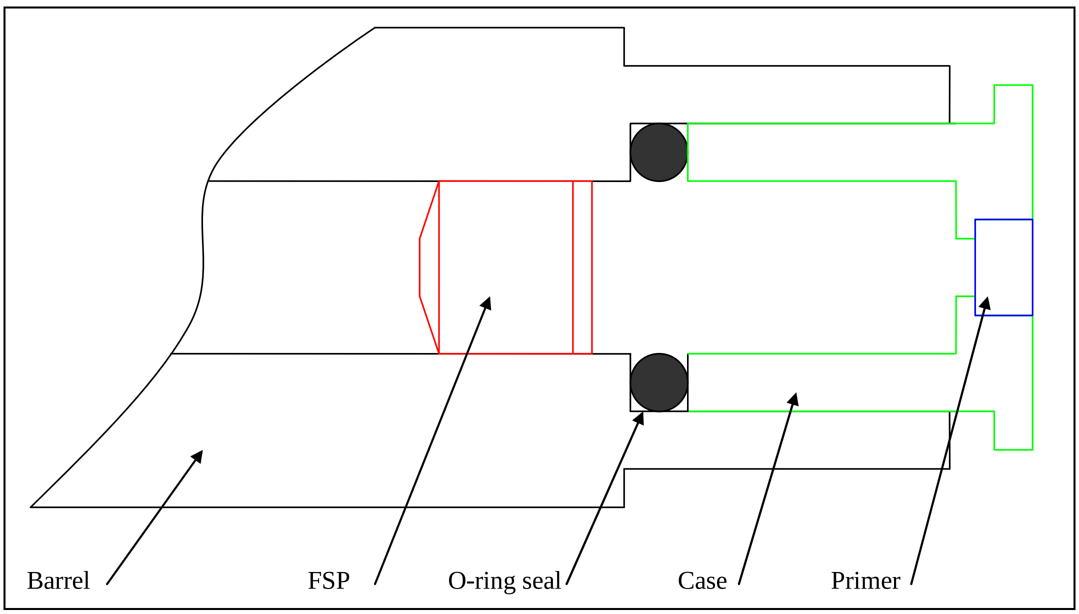

Figure 8. Cutaway view of chamber area of the gun system.

Testing was conducted using this powder, primer, and custom case to generate a velocity curve and define the performance for this system. An Oehler Chronograph system using model 57 infrared screens and/or flash radiographs were used to collect and record velocity data during testing. Figure 9 is a velocity curve generated during this testing. There were a couple things worth noting during this testing: first, it was necessary to install a shockwave arresting shield directly in front of the first chronograph screen when testing at subsonic (below the speed of sound) velocities to avoid getting false triggering of the chronograph caused by the shockwave traveling ahead of the projectile. A piece of plywood big enough to cover the opening of the screen with a 1-in hole cut in it for the fragment to pass through worked fine for this. Secondly, testing done at or below 0.22 gr of propellant produced inconsistent velocities, thus limiting this gun system to ~150 m/s minimum practical velocity.

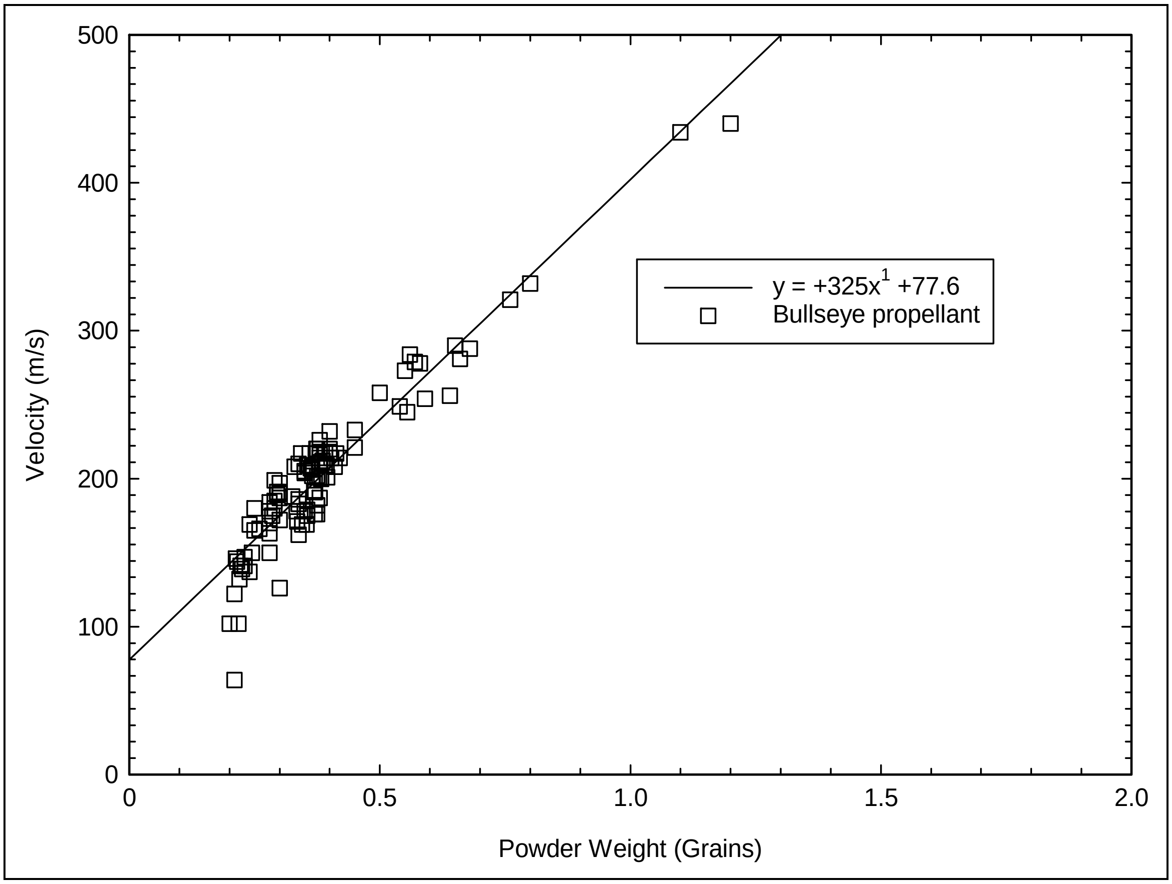

Figure 9. The 0.22-cal. launch velocity as a function of propellant load for XP12 barrel with custom case.

Examples of V50 data acquired using this gun system and described test methods are shown in table 1.

4. Conclusion

This custom gun system provided better velocity control for 0.22-cal. FSPs than a conventional 0.22-cal. gun system. This improved velocity control translated into reduced testing in order to establish V50 limit velocities. This system has been successfully used on numerous programs for materials at around 1psf areal density where low velocities are often required.

Table 1. Examples of V50 data acquired using XP12 custom gun system.

	AMB Shot No.	Pwd. Weight (gr)	Velocity (ft/s)	Result	Notes
Plate 1	7671	0.38	693	CP	CP = complete penetration
	7672	0.37	579	PP	PP = partial penetration
	7673	0.375	598	PP	ft/s = feet per second
	7674	0.39	687	CP	Used to calculate the V50
	7675	0.383	657	CP	—
	7676	0.379	658	CP	V50 ft/s = 641
	7677	0.37	652	PP	Std. dev. = 29
Plate 2	7741	0.3	646	CP	—
	7742	0.28	585	PP	—
	7743	0.29	653	CP	—
	7744	0.28	535	PP	—
	7745	0.285	573	PP	—
	7746	0.29	590	PP	V50 ft/s = 611
	7747	0.295	619	CP	Std. dev. = 34
Plate 3	7719	0.3	563	PP	—
	7720	0.45	764	CP	—
	7721	0.375	578	PP	—
	7722	0.413	713	CP	—
	7723	0.394	686	CP	—
	7724	0.375	720	CP	—
	7725	0.3	414	PP	—
	7726	0.338	609	CP	—
	7727	0.335	560	PP	V50 ft/s = 587
	7728	0.338	599	CP	Std. dev. = 21
Plate 4	7748	0.3	613	PP	—
	7749	0.38	613	PP	—
	7750	0.45	724	CP	—
	7751	0.41	684	CP	—
	7752	0.395	658	PP	—
	7753	0.403	702	CP	—
	7754	0.391	710	CP	V50 ft/s = 661
	7755	0.386	696	CP	Std. dev. = 40
Plate 5	7756	0.4	715	CP	—
	7757	0.36	712	CP	—
	7758	0.29	605	PP	—
	7759	0.325	617	PP	—
	7760	0.343	710	CP	—
	7761	0.334	583	PP	—
	7762	0.35	672	PP	—
	7763	0.355	574	PP	V50 ft/s = 689
	7764	0.365	662	PP	Std. dev. = 26

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